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HYDROGEOLOGIC INVESTIGATION
IRRIGATION & POTABLE WATER SUPPLY

NORTHERN FAUQUIER COUNTY SPORTS COMPLEX and COMMUNITY PARK
Fauquier County, Virginia

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I. INTRODUCTION

Emery & Garrett Groundwater, Inc. (EGGI) has prepared the following report regarding the development of an irrigation well and a potable groundwater supply well at the Sports Complex and Community Park Facility in Northern Fauquier County, Virginia. The park property is approximately 88 acres in size and is located north of Route 55, about 1 mile east of Marshall, Virginia (Figure 1). This park is designed to include eight recreation ball fields, two Frisbee courses, a swimming pool, and support buildings (Figure 2a). The work efforts for this groundwater exploration and development program were completed in accordance with the Fauquier County Subdivision Ordinance, Section 18, Hydrogeologic Testing, and the Virginia Department of Health Office of Drinking Water.

The goals of our study were to locate and develop sufficient groundwater resources to meet the irrigation needs of the park facilities and potable water needs for restrooms, concessions, and drinking fountains. It has been estimated, by the Fauquier County Government and Public Schools, that approximately 123 gallons per minute (gpm) will be required during peak demand periods to meet the irrigation needs of the park facilities and approximately 1,600 gpd will be required for the restrooms, concessions, and drinking fountains.

The demand for water will be met with two recently drilled water supply wells: FSC-4 and FSC-6 (Figures 1 and 2a). FSC-4 will be used as the irrigation supply well and FSC-6 as the potable water supply well.

EGGI has conducted a multi-phase hydrogeologic investigation that resulted in the construction and testing of the proposed wells. Phase I of the groundwater exploration program identified those areas within the project site considered hydrogeologically favorable for groundwater development. Phase II utilized geophysical surveys to identify specific geologic targets for test well drilling. These investigations were presented in a report entitled, *"Groundwater Investigation, Irrigation & Potable Water Supply – Northern Fauquier County Sports Complex and Community Park, Fauquier County, Virginia,"* Emery & Garrett Groundwater, Inc. (January, 2003).

This document provides a brief summary of the conclusions of the aforementioned report and subsequent work efforts that are relevant to this investigation. These subsequent work phases included the following:

1. *Drilling of exploratory wells* -- Six-inch diameter test wells were installed at five locations throughout the project site. For each well (Figure 2a, Table I, Appendix A), EGGI compiled geologic well logs, determined airlift yields[1], and analyzed water quality samples. All test well locations were approved and permitted by the Fauquier County Health Department and the Virginia Department of Health -- Office of Drinking Water before drilling began.

2. *Converting selected test wells into production wells* -- EGGI converted test wells FSC-4 and FSC-1 to eight-inch diameter production wells and test well FSC-6 into a 6-inch potable supply well. The wells were developed and airlift yields were measured. As a result of these preliminary airlift yield measurements, it was determined that the yield of well FSC-4 would serve as the primary irrigation well for the sports complex and FSC-1 should be retained as an emergency back-up irrigation well.

3. *Hydrogeologic testing of drilled production wells* -- Constant rate pumping tests were carried out simultaneously on wells FSC-4 and FSC-6. Irrigation Well FSC-4 was pumped for 72 hours and potable supply Well FSC-6 was pumped for 52 hours. During the pumping tests, water levels were monitored in the two pumping wells, three on-site test wells, and in eighteen off-site wells (Figure 1, Table II). After pumping ceased, water levels continued to be monitored in order to assess groundwater recharge/recovery rates.

4. *Hydrogeologic assessment of pumping data* -- The hydrogeologic data generated by the investigation (pre-pumping, pumping, and post-pumping test data) were used to determine whether groundwater supplies of sufficient quantity were available to satisfy the irrigation and potable water supply needs of the Sports Complex and Community Park.

5. *Water quality assessment* -- Water samples were collected from both wells and analyzed for Primary and Secondary EPA Drinking Water Standards at a State-approved laboratory.

The results of this study indicate that groundwater resources can be withdrawn from on-site irrigation Well FSC-4 at a maximum rate of 125 gpm and Well FSC-6 is capable of yielding

[1] Airlift tests involve using the drill rig to "airlift" the water out of the well during the drilling process such that a preliminary measurement of the rate of water produced from a well can be made.

15 gpm (21,600 gpd) to meet on-site potable water supply needs. A discussion of the recommended pumping schedule and anticipated off-site impacts concludes the report.

II. HYDROGEOLOGY OF THE PROJECT SITE

A. BEDROCK GEOLOGY

Groundwater resources must be derived from available bedrock aquifers within the project site. The geology of the study area was investigated through a detailed program of geologic field mapping. As a part of this mapping exercise, EGGI compiled a geologic base map for the study area (for reference, see Plate 1, View B of EGGI's Groundwater Investigation Report, January 2003). Soil exposures and a limited number of rock outcrops were identified and evaluated by EGGI geologists within the study area.

Based upon EGGI's analysis, it was determined that one main rock unit underlies the project site: fine-grained metagranite of the Marshall Metagranite Formation. This formation is primarily comprised of rocks characterized as dark-gray, fine-grained, and composed mainly of quartz, plagioclase, and potassium feldspar. In addition, although not mapped, meta-mafic rocks, such as greenstone and greenschist, often occur as lenses within the metagranite of the Marshall Formation. The foliation[2] in the rocks trends from north to northeast and dips to the east at shallow to steep angles.

B. GROUNDWATER RECHARGE ANALYSIS

Wells FSC-4 and FSC-6 are located nearby a tributary that drains into Piney Branch, which drains into Broad Run. Groundwater flow directions beneath the monitored area generally mimic surface topography (Figure 1). The water level data used to construct the groundwater contour map was collected immediately prior to the start of the groundwater withdrawal test. Elevations were estimated based on interpolation of surface topography using existing topographic maps and are believed to be accurate within +/- 5 feet.

In the Piedmont of Virginia and nearby Maryland, estimates of groundwater recharge have ranged from 8.4 inches per year (Pavich, 1986), to 10.5 inches per year (Richardson, 1980), to 11.3 inches per year (Nutter and Otton, 1969). Therefore, a value of 10 inches per year is considered by EGGI to be appropriate for the Sports Complex and Community Park Facility study area.

A recharge value of 10 inches per year is equivalent to approximately 476,100 gallons per day per square mile. The subject property covers an area of approximately 0.14 square miles (88 acres). A contributing watershed that is approximately 0.26 square miles (168 acres) drains to the site (Figure 1). Precipitation falling within the limits of the property and within the area of the contributing watershed provides an estimate of 123,786 gpd of groundwater recharge. Based upon these estimates, the pumping wells on the Sports Complex and Community Park Facility property will likely draw groundwater from a greater area during extended pumping periods than

[2] Foliation is the parallel alignment of minerals developed during the metamorphism and deformation of the rocks.

that which is provided by the development property alone; this is not uncommon for high yielding production wells. However, since he irrigation well will not be pumped year round, but rather four to five months of the year, it is anticipated that annual groundwater recharge to the property will exceed annual groundwater withdrawals.

C. PROXIMITY TO CONTAMINANT THREATS

The quality of groundwater resources can be adversely affected by land uses that allow contaminants to migrate into underlying bedrock aquifers. Therefore, one element of EGGI's groundwater resource investigation was to review the presence of potential contaminant threats to groundwater quality. This survey was carried out to a minimum distance of 2000 feet around the perimeter of the Community Complex. EGGI conducted windshield surveys around the study area to highlight land uses that, according to EGGI's judgment, may threaten groundwater quality. Environmental Data Resources, Inc. (EDR) of Southport, Connecticut, completed a compilation of available environmental databases.

EDR's compilation identified six known potential contaminant sources within 2000 feet of the Community Complex project site (Figure 2b, Appendix A). One additional site, the Belvoir Store is located 3500 feet away. EGGI reviewed files at the Virginia Department of Environmental Quality (VDEQ) regarding five of the seven properties, including: Shockey Precast[3], Morgan Oil, Allied Wood Products[4], the Jeris Residence, and the Belvoir Store. Four of the sites reviewed (Shockey Precast, Morgan Oil, Allied Wood Products, and the Jeris property) had only minor incidences and their environmental cases have been closed by the VDEQ. The Benhard Property case involves the creation of a pond and the filling of a perennial stream and, therefore, is not relevant as a contaminant threat to groundwater. The Coleman School is listed under the leaking underground tank file, but no details were available regarding the extent of groundwater contamination.

The only site that is currently open and under investigation is the Belvoir Store, which is located approximately 3500 feet south (down gradient) of the Community Complex. The Belvoir Store was formally used as a convenience store and a gas station and has been closed since 1998. Petroleum contamination was detected in the excavation pits during the removal of underground storage tanks (UST) in1999 and in 2001. As a result, three multi-phase extraction events have been performed and latest laboratory results (samples collected on February 24, 2003) indicate that the Belvoir Store site is still impacted by petroleum hydrocarbons. However, given that most of the petroleum contamination at the Belvoir Store in contained within the limits of the property and the property is located down gradient of the proposed Sports Complex, the contamination at the Belvoir Store is not anticipated to pose a significant threat.

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[3] This is the name of the business as reported by EDR. The business is currently known as Shockey Concrete.
[4] This is the name of the business as reported by EDR. The business is currently known as Heritage Hardwoods.

Windshield surveys identified nine other potential contamination sources within the vicinity of the Community Complex[5] (Figure 2b). None of these sites have any documented incidents that have adversely impacted groundwater quality.

III. PUMPING TEST DESIGN

A. PUMPING TEST PROCEDURES

Using a submersible pump powered by a portable generator, Well FSC-4 was pumped continuously for 72 hours at a constant rate of 150 gpm (216,000 gpd). Well FSC-6 was pumped continuously for 52 hours at a constant rate of 15 gpm (21,600 gpd). The pumping rate for Well FSC-4 was monitored using an orifice weir and the pumping rate for Well FSC-6 was controlled using an in-line flowmeter (Figure 3). Volumetric measurements for each pumping well were taken using a stopwatch and a calibrated container. Water level measurements made in each well were taken at regular, pre-determined intervals during the pumping and recovery periods. The water level measurements were made using a combination of manual and automated measurements, both accurate to within 0.01 feet. The water level data collected during the pumping test are presented in Appendix B.

B. GROUNDWATER MONITORING

During the pumping test, water level responses were observed in a total of 21 monitoring wells in the bedrock aquifer (Figure 1, Plate 1, Table II). Groundwater monitoring locations and their associated descriptions are as follows:

- Seven off-site *domestic* wells were used for groundwater monitoring.
- Eleven off-site *commercial* or *public* wells were monitored. These included: two proposed public supply wells for the Town of Marshall (PW-1 and PW-2), two public supply wells managed by the Fauquier County Water and Sanitation Authority (Church and Lane wells), one well that services the Coleman Elementary School, and six wells that serve local businesses (Adgate, Heritage Hardwoods, Fauquier Livestock Exchange, Morgan Oil, Piedmont Equine Practice Center, and Shockey Concrete).
- Three on-site wells that were monitored included two 6-inch exploratory wells (FSC-2 and FSC-3) and one 8-inch backup production well (FSC-1).

C. MONITORING OF CLIMATOLOGICAL EVENTS

During the pumping test there were no significant precipitation events (Plate 1, Figure 4). However, six days prior to the pumping test a total of 3.04 inches of rainfall were recorded at Washington Dulles Airport. One day following the termination of pumping, 0.27 inches of rainfall was recorded at Washington Dulles Airport. There was no significant water level changes observed in the wells monitored as a result of these precipitation events. A recording

[5] Several of these sites are considered as "potential" threats to groundwater quality. Long-term groundwater monitoring of this local area is recommended as part of a Groundwater Use Management Plan for this area.

barometer was used to evaluate water level responses in the bedrock aquifer due to atmospheric pressure changes (Plate 1).

IV. PUMPING TEST RESULTS

A. IRRIGATION WELL FSC-4: RESPONSE TO PUMPING

A step drawdown test was conducted on Well FSC-4 using pumping rates of 100, 150, 200, and 250 gpm (Figure 5). Each step lasted 60 minutes. Total drawdown at the conclusion of the four-hour test was 61.82 feet and the specific capacity was 0.75 gallons per minute per foot of drawdown (gpm/ft). When the rate increased from 150 to 200 gpm, a significant jump in the amount of drawdown occurred (the specific capacity decreased). Therefore, based upon the results of step drawdown test, especially with regard to the location of water-bearing zones in FSC-4, a pumping rate of 150 gpm was chosen for the long-term, constant rate test.

The long-term constant rate pumping test performed on Well FSC-4 began on August 18, 2003, and continued for 72 hours without interruption (Plate 1, Table III). The pumping rate maintained during the test was 150 gpm. Plots of water level versus time and water level versus logarithmic time reflect the pumping response of FSC-4 (Figures 6 and 7). The water level response in FSC-4 shows that the majority of the water level decline observed during the pumping period occurred within the first 12 hours of the test; this was followed by gradual flattening of the drawdown curve. However, the curve never reached a completely stable drawdown level. The rate of drawdown was modest for the duration of the test; however, it indicates that a sufficient recharge source was not intercepted during the pumping period to balance all of the groundwater being withdrawn during this bedrock aquifer stress test.

At the conclusion of pumping, drawdown in Well FSC-4 totaled 81.67 feet, which translates to a specific capacity of 1.84 gpm/ft (Table III). The maximum available drawdown in Well FSC-4 is 268.5 feet, based upon the location of the first major water-bearing fracture at 275 feet below ground. *Therefore, only 30 percent of the available drawdown was utilized during this testing program* (Table III).

In general, groundwater recharge to a bedrock aquifer is considered favorable when a well recovers fully during a post-pumping time interval equal to the length of the pumping period. Water levels in Well FSC-4 recovered to 84% of the pumping-induced drawdown after 72 hours and, therefore, full recovery was never achieved during this specific testing period. Residual drawdown (the portion that was not yet replenished) was 3.18 feet after six days of recovery. This means that a portion of the groundwater withdrawn was borrowed from storage during the testing period resulting in the temporary lowering of the water table. Because it is likely that additional deficits in the groundwater table will occur during dry seasons, the removal of groundwater from storage will play an important role in the management of the groundwater supply. Replenishment of the groundwater table during the wet season (non-irrigation season) will be essential to maintaining safe water levels in the local bedrock aquifer.

B. PUBLIC SUPPLY WELL FSC-6: RESPONSE TO PUMPING

Well FSC-6 was pumped at a rate of 15 gpm for the duration of the 52-hour pumping test (Plate 1, Table III). Well FSC-6 began pumping twenty hours after Well FSC-4. Interference drawdown of approximately 4.5 feet was recorded in FSC-6 during the first twenty hours of pumping at Well FSC-4. Water level variations of up to seven feet were observed in FSC-6 throughout the groundwater monitoring period (both pre-pumping, pumping, and post-pumping periods), which EGGI believes is attributable to the pumping of an off-site domestic or commercial well.

The water level drawdown plots (Figures 8 and 9) show the rate of drawdown observed in Well FSC-6. The rate of water level decline was greatest during the first twelve hours of pumping followed by a nearly constant drawdown for the remainder of the testing period (Figure 8). Shown on a logarithmic time scale, the drawdown curve gradually flattens, indicating that recharge to the bedrock aquifer equals (or exceeds) the withdrawal rate of 15 gpm (Figure 9). At the conclusion of pumping, drawdown in Well FSC-6 totaled 45.10 feet, which translates to a specific capacity of 0.33 gpm/ft (Table IV).

The total available drawdown in FSC-6 is about 240 feet (measured above the uppermost significant water-bearing fracture). *Thus, at the conclusion of the pumping test, only 18% of the available drawdown had been utilized.* After a time period equal to the pumping interval, 97% of the pumping-induced drawdown had recovered.

C. GROUNDWATER MONITORING WELLS – RESPONSE TO PUMPING

The water level response plots for each monitoring well are shown on Plate 1 and in Appendix B. During the pumping test of Wells FSC-4 and FSC-6, water level impacts were observed at 19 of the 21 groundwater monitoring locations, including seven domestic wells, six off-site wells that serve local businesses, the well at the Coleman Elementary School, the two proposed public supply wells for the Town of Marshall, and three on site wells. A contour map of pumping-induced drawdown during the pumping test is presented on Plate 1. In addition to the observed water level impacts associated with the pumping of wells FSC-4 and FSC-6, many of the monitoring wells are also being impacted by existing off-site well(s). The responses observed show that there is widespread interconnection of underlying transmissive bedrock features.

1. Water Level Response Observed in Domestic Wells

Pumping-induced drawdowns were observed in all seven of the domestic wells monitored (Plate 1, Table IV, and Appendix B). The water level impacts ranged from 2.13 feet in the Curtis well to 47.59 feet in Orleans well (Table IV). Distances between the monitoring wells and the pumping wells varied between 370 feet and 1,920 feet (Table II).

The largest water level impacts on the domestic wells were observed at the Orleans and Glascock residences. The water level in the Orleans domestic well declined 47.59 feet due to the pumping of Irrigation Well FSC-4. This 216-foot deep domestic well is located 1,260 feet from

Irrigation Well FSC-4. The yield of the Orleans well is unknown. The water level in the Glascock domestic well declined slightly more than 27 feet due to the pumping of wells FSC-4 and FSC-6. The majority of the drawdown (21 feet) observed in the Glascock well was due to the pumping of Potable Supply Well FSC-6, which is approximately 370 feet away. The yield of the Glascock well is reported to be 0.75 gpm and the well is 400 feet deep (Table II).

The remaining five domestic wells (Bono, Curtis, Cleveland, Leach, and Rice) had only minor water level impacts (less than 5 feet) due the pumping of Wells FSC-4 and FSC-6. At no time were any of the domestic wells impacted to such an extent that the pumping wells interfered with the usability of the domestic wells.

Monitoring of water levels during the recovery portion of the pumping test indicates that groundwater at the Curtis, Leach, Orleans, and Rice wells was temporarily removed from storage during the testing period. In contrast, the water level in the Bono and Cleveland wells recovered to pre-pumping levels within 48 hours of recovery.

2. Water Level Response Observed in the Off-Site Wells that Serve Local Businesses

The Adgate property consists of an office and a self-storage facility. The water level in the Adgate well declined 46.35 feet due to the pumping of Irrigation Well FSC-4, which is 1,370 away. The Adgate well is 265 feet deep and the yield is unknown.

Heritage Hardwoods is a lumber milling facility. The well on the property responded to the pumping of Irrigation well FSC-4 and possibly potable supply well FSC-6 with 1.71 feet of drawdown. Based upon the short-term downward spikes of the water level data seen throughout the entire groundwater-monitoring period (both pre-testing and post-testing periods), it is evident that the water level in the Heritage Hardwoods well is also influenced by the intermittent use of another unknown local well.

The water level in the Fauquier Livestock Exchange well responded to the pumping of Irrigation Well FSC-4 with 5.82 feet of drawdown. The well monitored is *not* in current use. The Livestock Exchange Staff reported to EGGI that the well would likely be abandoned. Unknown to EGGI during the installation of the groundwater monitoring equipment, there is apparently another well on the Fauquier Livestock Exchange Property that *is* in current use that was not monitored.

The Morgan Oil well responded to the pumping of Irrigation Well FSC-4 with 3.45 feet of drawdown. The distance between the wells is 2,910 feet. The yield of the Morgan Oil well is 28 gpm and the depth of the well is 225 feet. Similar to the short-term downward spikes in the Heritage Hardwoods Well, the Morgan Oil Well is influenced by the intermittent use of another local well.

The water in the well monitored at the Piedmont Equine Practice Center declined 23.35 feet due to the pumping of Irrigation Well FSC-4. Throughout the monitoring period the Piedmont Equine Center well was *not* in use. The property owner reported to EGGI that the well

would be returned to service when a new Center is constructed in the near future. The short-term downward spikes of the water level data recorded during the pumping and recovery interval is caused by another off-site well that is in current use.

The well on the Shockey Concrete property provides water for the on-site office and the concrete plant. The water level in the Shockey well declined 6.73 feet due to the pumping of Irrigation Well FSC-4. Long duration pumping events, indicated by downward spikes, suggest the Shockey Well is frequently pumped for several hours per day.

3. Water Level Response Observed in the Off-Site Production Wells

The well at the Coleman Elementary School responded to the pumping of Irrigation Well FSC-4 with 24.27 feet of drawdown. The distance between the wells is 1,170 feet. The depth of the Coleman School well is 220 feet.

Less than one tenth of a foot of drawdown (if any) was observed in the proposed Marshall Production Wells PW-1 and PW-2 due the pumping of Irrigation Well FSC-4. Wells PW-1 and PW-2 are located over one mile away from Irrigation Well FSC-4.

The simultaneous pumping of Irrigation Well FSC-4 and Potable Supply Well FSC-6 caused no discernable impacts to the Church well or the Lane well.

4. Water Level Response Observed in the On-Site Monitoring Wells

Water levels in all the on-site monitoring wells (FSC-1, FSC-2, and FSC-3) responded to the pumping of Wells FSC-4 and FSC-6. The water level impacts ranged from 8.04 feet in FSC-2 to 47.63 feet in FSC-1 (Table IV). Distances between the monitoring wells and the pumping wells vary between 570 feet and 1,480 feet (Table II).

The pumping of irrigation Well FSC-4 impacted water levels observed in wells FSC-1 and FSC-2. Pumping of potable supply Well FSC-6 caused a water level decline of 13.33 feet in Well FSC-3. Another off-site well likely caused additional water level declines observed in FSC-3, as suggested by short-term downward spikes of the water level data during the pumping period.

D. PROJECTION OF ANTICIPATED IMPACTS IN PUMPING AND MONITORING WELLS

As a means of projecting the anticipated impact of pumping Wells FSC-4 and FSC-6 on neighboring wells, 90-day water level projections were made for each pumping response plot. The projections assumed that the two proposed wells pumped continuously for 90 days with no shutdowns at the rates utilized during the pumping test. This is not the recommended pumping schedule, but it does allow one to simulate an extended groundwater withdrawal "stress" condition on the bedrock aquifer. Graphical projections of water level drawdown versus logarithmic time were used to assess anticipated impacts on water level drawdown on each well. The results of these individual extrapolations are shown on Table IV.

Under these 90-day continuous pumping scenarios, projected impacts on several off-site wells are substantial. The Adgate, Piedmont Equine Center, Coleman School, and Orleans wells would all likely experience water level declines of more than 45 feet. It is possible that such long-term simultaneous pumping of the new wells, especially the pumping of irrigation Well FSC-4 (i.e., 90 days), could interfere with the normal use of one or more neighboring domestic wells. EGGI has prepared an operation plan that is focused on diminishing the potential for off-site adverse impacts to occur (Section VI).

V. WATER CHEMISTRY

Water quality samples were collected from Wells FSC-4 and FSC-6 throughout the pumping test and again shortly before the termination of the pumping test. The samples collected during the test were analyzed using field methods for a limited number of variables (Table V). Water samples from Potable Supply Well FSC-6 were submitted to National Testing Laboratories of Ypsilanti, Michigan and Virginia Division of Consolidated Laboratory Services (Table VI and Appendix C). Twenty samples from FSC-6 (taken at one-hour intervals over the last 30 hours of the tests) were submitted to Joiner Micro Laboratories, Inc. of Warrenton, Virginia, for bacterial analysis. Water samples from Irrigation Well FSC-4 were submitted to National Testing Laboratories of Ypsilanti, Michigan.

All of the analytical results received to date indicate that the water from Well FSC-6 is of good quality and meets all primary and secondary drinking water standards, with the exception of iron and manganese. Iron and manganese are nuisance parameters, causing staining and unpleasant odors and tastes, but neither represents a health risk. Routine treatment methods can be used to prevent the iron and manganese from being a serious concern. No coliform bacteria were identified in any of the 20 samples collected from the pumping well.

Toluene was detected in Well FSC-6 (0.5 ppb) by the Virginia State Laboratory but not detected by National Testing Laboratories. The likely cause of this very low level of toluene is either laboratory contamination or electrical tape used on pump wiring during installation. The drinking water standard for toluene is 1000 mg/l.

The quality of the water from Well FSC-4 is considered excellent for use as irrigation water for the proposed Sports Complex.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The performance and analysis of the long-term pumping test on Wells FSC-4 and FSC-6 served to document the following:

- The total volume of groundwater removed from irrigation Well FSC-4 and potable supply Well FSC-6 during the testing period was 694,800 gallons. Well FSC-4 was pumped at a continuous rate of 150 gpm for a period of 72

hours (216,000 gpd). Well FSC-6 was pumped simultaneously with Well FSC-4 at a continuous rate of 15 gpm (21,600 gpd) for a period of 52 hours. At the conclusion of the pumping period, the water level in Well FSC-4 had dropped to a depth of approximately 88 feet below the top of the well casing. The water level in Well FSC-6 had dropped to a level of approximately 56 feet below the top of the casing.

- Groundwater levels were monitored in 21 observation wells for a *minimum* period of 18 days between August 12 and August 30, 2003. (However, most of these observation wells were monitored more than 25 days and several wells were actually monitored for a period of 42 days.) During this timeframe, water level data in each well were collected and recorded every 30 minutes. Eighteen of these wells were located off site and included commercial wells, residential wells, community supply wells, and a school well (Coleman School).

- Water levels in 19 of the 21 observation wells were impacted as a result of pumping Wells FSC-4 and FSC-6. At no time were any of the off-site domestic, business, or production wells *adversely* impacted such that the simultaneous pumping of wells FSC-4 and FSC-6 interfered with the immediate usability of the off-site wells. The pumping test performed on these wells was accomplished in a manner intended to *cause a maximum stress on the local bedrock aquifer*. Actual groundwater withdrawals from these wells will be less than that volume of water withdrawn during this maximum groundwater withdrawal testing period.

- The greatest impacts observed in off-site wells, caused by the pumping of proposed wells FSC-4 and FSC-6, were recorded at the Glascock, Orleans, Adgate, Piedmont Equine Practice Center, and the Coleman School. The water level interference measured during the testing period ranged from 23.35 to 47.59 feet in these wells (Table IV). If the recommended pumping schedule is maintained, as presented in Section VI-B of this report, the anticipated drawdown in these wells should not adversely impair/limit the usability of these off-site wells.

- Neither the FCWSA Church Well nor the FCWSA Lane Well responded to the pumping of the proposed irrigation and potable supply wells. These wells currently supply the Town of Marshall with its potable water needs.

- The water produced from Wells FSC-4 and FSC-6 is of very good quality. The water from Well FSC-6 meets all EPA Primary and Secondary Drinking Water Standards, except for iron and manganese, which will require routine treatment before consumption. The water from FSC-4 meets all EPA Primary and Secondary Drinking Water Standards and is considered excellent for use as irrigation water.

B. RECOMMENDED OPERATION PLAN

The data included in the following table should be used to help design the water supply system for the proposed Sports Complex. Our recommendations for pump setting and pumping capacity are also presented below.

Production Well Identification	Depths of Significant Water-bearing Zone(s) (feet)*	Recommended Pump Setting (feet)*	Recommended Not-to-Exceed Pumping Water Level (feet)*	Recommended Not-to-Exceed Pumping Rate (gpm)
FSC-4	102, 275, 383	260	100	125
FSC-6	150, 250	230	100	15

*feet below ground level

- *Well FSC-6 can be pumped as needed at a maximum rate of 15 gpm.* EGGI does not believe that pumping this well to serve the on-site potable water needs will cause adverse off-site impacts.

- *Well FSC-4 should be pumped according to a restricted schedule.* It is recommended that Well FSC-4 be limited to pumping periods of 8 to 12 hours per day with the remainder of each 24-hour period left to allow for the recovery of groundwater levels. In addition, pumping should only occur a maximum of five to six days per week allowing one to two days per week for further recovery of groundwater levels. This will serve to diminish the potential for causing excessive drawdown in off-site wells.

- *Pumping water levels in the two production wells (FSC-4 and FSC-6) should be maintained above the primary water-bearing zones.* The recommended pump settings will ensure that this will occur. This will limit the degree of cascading water entering the borehole. Minimizing such cascading is critical for the long-term maintenance of the pumping well because it prevents the introduction of oxygen into the groundwater, which can lead to problems with bacterial growth, and oxidation of minerals.

- *Well FSC-1 should be retained as an emergency back-up irrigation supply well.*[6] Well FSC-1 is a high yield well and produced approximately 214 gpm at the time if was drilled. This well is, however, hydraulically connected with Well FSC-4 and there would be no net gain in water production if both wells were pumped simultaneously. Since Well FSC-1 is located closer to the property boundary and, therefore, nearer to off-site wells, EGGI strongly recommends that this well be reserved for use only in emergency conditions (e.g., if FSC-4 is rendered unusable due to an unexpected catastrophic failure of some kind).

[6] Well FSC-1 has not been pump tested, so its sustainable yield and recommended pump settings are not known at this time.

- *Well FSC-3 should be abandoned according to Virginia State and Fauquier County regulations.*

C. RECOMMENDED GROUNDWATER MONITORING PLAN

EGGI strongly recommends that a long-term groundwater monitoring plan be implemented for the purpose of establishing a groundwater database and to provide the necessary information to determine if the groundwater withdrawal pumping schedule presented herein will require modification. The groundwater monitoring program would be conducted using three groups of wells: (1) The two production wells to be used on the Complex property (FSC-4 and FSC-6); (2) two existing wells located on the Complex property (FSC-1 and FSC-2); and (3) two or more off-site wells selected from the following preferred candidate locations: Coleman School, Orleans, Adgate, Glascock, and Piedmont Equine Practice Center.

1. Water Level Monitoring

a) Monitoring of production Wells FSC-4 and FSC-6

EGGI recommends that a means for recording water levels *and* pumping withdrawals be installed in both wells FSC-4 and FSC-6. Water level data should be recorded every two hours during the irrigation season. During non-irrigation periods, water levels should be recorded a minimum of once per day. Daily monitoring should be continued for a minimum of the first two years of irrigation to establish a groundwater level database.

b) Monitoring of on-site Wells FSC-1 and FSC-2

To use both FSC-1 and FSC-2 as monitoring wells will require that an automated water level recording instrument be installed in each well. Wells FSC-1 and FSC-2[7] are effective locations to monitor water level impacts resulting from pumping Irrigation Well FSC-4. Water levels in each well should be recorded every two hours during the irrigation season. During non-irrigation periods, water levels should be recorded a minimum of once per day. Daily monitoring should be continued at least for the first two years of irrigation to establish a long-term groundwater level database.

[7] Well FSC-2 currently has temporary surface casing installed and will need to be converted to an approved monitoring well according to health department construction guidelines.

c) Monitoring of two or more off-site wells

EGGI also recommends that the Coleman School and one or more other off-site well(s) (Orleans, Adgate, Glascock, Piedmont Equine Practice Center) be used as permanent groundwater monitoring wells. Automated water level monitoring equipment should be installed in each well and water level data collected and recorded daily for a period of two years. In order to accomplish this, the private landowner will need to provide permission for such monitoring to occur.

2. Water Quality Monitoring

Several potential threats to groundwater quality do exist within the area influenced by the pumping of wells FSC-6 and FSC-4 (Plate 1, Figure 2b). Although no contamination, associated with past and/or present land uses, was detected in the groundwater produced from wells FSC-6 and FSC-4 during the groundwater quality testing program, it is recommended that groundwater withdrawals for use at the Sports Complex be carefully monitored over time. EGGI recommends that water samples be collected from both wells FSC-4 and FSC-6 twice per year for the first two irrigation seasons and analyzed for EPA Primary and Secondary Drinking Water Standards. We recommend that groundwater sampling occur once at the beginning of each irrigation season (May/June) and once near the end of each irrigation season (September/October).

3. Monitoring of Groundwater Withdrawals from Wells FSC-4 and FSC-6

A flow meter capable of permanently recording groundwater withdrawals from each well should be installed. Daily pumping volumes should be recorded for the first two irrigation seasons to assure that pumped groundwater sources are not exceeding recommended volumes of groundwater withdrawal.

4. Development of Long-term Groundwater Use Management Plan

The local community depends entirely upon groundwater withdrawals to maintain their daily livelihood (e.g., school, businesses, and local residences). Although wells FSC-4 and FSC-6 are capable of being pumped at greater rates than what is recommended herein, it is EGGI's professional opinion that the groundwater withdrawal rates, as identified in the report, must be maintained. The hydrogeologic data collected during the groundwater monitoring program will determine whether the proposed groundwater withdrawal schedule (and/or groundwater monitoring plan) will require modification.

We believe that the limitation on groundwater withdrawal, as described, will aid in protecting the wells (and local bedrock aquifer) from potential off-site sources of contamination, limit the potential for adverse impacts to occur to off-site domestic wells, and allow the collection of additional (long-term) water quality and water level data needed to assess whether additional volumes of groundwater can safely be removed from the local bedrock aquifer.

We recommend that the data collected from the groundwater monitoring program be compiled and reviewed annually by a professional hydrogeologist. These data should be used to establish a long-term Groundwater Use Management Plan that is focused on protecting the availability and usability of groundwater resources for both the proposed Complex and local community.

VII. LIMITATIONS

EGGI has collected and evaluated the available technical data according to the Fauquier County Subdivision Ordinance, Section 18, Hydrogeologic Testing, and Virginia Health Department requirements. It is to be recognized that the testing program was limited to that which is presented in this report and occurred during a specific climatic period. The recommendations, statements, and findings provided herein represent EGGI's professional opinion based upon the data collected and do not constitute a warranty written or implied.

VIII. REFERENCES

Emery & Garrett Groundwater, Inc., January 2003, Groundwater Investigation, Irrigation & Potable Water Supply – Northern Fauquier County Sports Complex and Community Park, Fauquier County, Virginia.

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